# Effects of closed forest on diameter class structure of *Quercus mongolica* forest in eastern area of Xiaoxing'an Mountains

YANG Feng-jian, TANG Zhong-hua, ZU Yuan-gang
(*Key Laboratory of Forest Plant Ecology, Northeast Forestry University, Harbin 150040, P. R. China*)

**Abstract**: In eastern area of Xiaoxing'an Mountains, Heilongjiang Province (44º4'-47º26 N', 126º33'-131º41'E) the diameter-class structure of *Quercus mongolica* forest after different closed time was studied in the plots with different slope direction. Six repetitive plots within 5-year, 16-year and 24-year closed *Q. mongolica* forests were selected in sunny slope and shade slope, respectively. The area of each plot was 20 m×20 m. Diameter at breast height (DBH), tree height and canopy diameter of all the trees were measured. Six classes of diameter were determined as 2, 4, 6, 8, 10, and 12 depending on the range of DBH (0-3, 3-5, 5-7, 7-9, 9-11, and 11-13 cm). The results showed that: 1) After 5-year closed treatment, the population quantities *Q. mongolica, Tilia mandshurica* and *Ulmsis laciniata* decreased with the increase in diameter class, which indicated they were healthy populations; 2) After 16- year closed treatment the tree number of *Tilia mandshurica* and *Ulmsis laciniata* decreased because of canopy coverage increasing and became the associated species in *Q. mongolica* population; 3) *Q. mongolica*, after 24-year closed treatment, became dominant species; 4) Canopy coverage increased more rapidly in sunny slope than that in shade slope. Recession of *Tilia mandshurica* and *Ulmsis laciniata* populations in sunny slope was more obviously than that in shade slope.

**Keywords:** Closed forest; *Q. mongolica* forest; Diameter-class structure
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## Introduction

The term of closed forest used in this studied means that the hills are setting apart for tree growing. The treatment of closing forest can usually accelerate the process of forest recovery because natural succession without further disturbance can happen in a relative short time. Under the condition of closed forest, the structure of forest diameter class, which is used as an indicator of individual growth and dynamics of dominant population, is closely related to the structure, function and dynamic of the community. Furthermore, forest-developing direction can also be predicted by the characters of diameter-class structure (Palik *et al.* 1992; Oliver *et al.* 1990). The studies on closed forest began at the end of the 1940s in China, however, further research of closed forest, such as forest distribution pattern, community type and nutrition dynamic, was conducted after the 1980s (Foggie 1947; Foggie 1953; Ni 1989). In the eastern mountain area of Xiaoxing'an Mountains, Heilongjiang Province, the mainly recovered secondary forest from cutting blank is *Quercus mongolica* forest. This paper studied the diameter-class structure and closed time of *Q. mongolica* forest, aiming at the sustainable development of forest management in this area.

**Biography**: YANG Feng-jian (1971-), male, lecturer in Key Laboratory of Forest Plant Ecology, Northeast Forestry University, Harbin 150040, P R China.
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## Study site

The study site is located in the eastern area of Xiaoxing'an Mountains, Heilongjiang Province (44º4'-47º26' N, 126º33'-131º41'E, 400-1000 m a.s.l), with main physiognomy type of low hills and valleys. This area belongs to Xiaoxin'an-Laoye Mountains flora, with the warm temperate continent monsoon climate, and climax vegetation is the mixed forest of broadleaved and *Pinus koraiesnsis* species (Zhou 1986).

## Study methods

The typical *Q. mongolica* forest with different closed time in shade and sunny slopes was chosen as sampling forest in eastern area of Xiaoxing'an Mountains. Six repetitive plots within 5-year, 16-year and 24-year closed *Q. mongolica* forests were selected in sunny slope and shade slope, respectively. The area of each plot was 20 m×20 m. Diameter at breast height (DBH), tree height and canopy diameter of all the trees were measured in those plots. Six classes of diameter were determined as 2, 4, 6, 8, 10, and 12 depending on the range of DBH (0-3, 3-5, 5-7, 7-9, 9-11, and 11-13 cm). The width of canopy was measured from south to north and from west to east. With an average value of canopy diameter (A), the Canopy coverage ($C_C$) was calculated by the following equation:

$$C_C = \sum_{i=1}^{n} \pi (\frac{A}{2})^2 / 400 \quad (1)$$

Where, $C_C$ is the canopy coverage, $A$ is canopy diameter; and $i$ is tree number.

## Results and discussion

### Canopy coverage and tree height

Investigation result showed that the canopy coverage and tree height greatly increased with the increase in closed time in sunny and shade slopes (Table 1). According to the results calculated by Equation (1), After 16 years of closed treatment, the canopy coverage of *Q. mongolica* forest reached 84.37% in sunny slope and 68.49% in shade slope. After 24 years, the canopy coverage of the forest increased to 84% in shade slope and to 88.71% in sunny slope. The possible explanation for the difference in canopy coverage between sunny and shade slopes is that sunny slope receives relative stronger radiation and higher temperature. In case of closed time treatments, similar tendency was observed in tree height. The maximum of tree height in sunny slope was 13.72 m, which is higher than the maximum (11.39 m) of tree height in shade slope.

**Table 1. Canopy coverage and tree height of *Quercus mongolica* forest with different closed time in sunny and shade slopes of eastern area of Xiaoxing'an Mountains**

| Exposure | Closed time/a | Canopy coverage (%) | Standard deviation | Tree height /m | Standard deviation |
|---|---|---|---|---|---|
| Sunny slope | 5 | 63.25 | 3.82 | 6.81 | 0.36 |
| | 16 | 84.37 | 5.93 | 8.76 | 0.89 |
| | 24 | 88.71 | 7.41 | 13.72 | 0.76 |
| Shade slope | 5 | 59.33 | 4.66 | 6.54 | 0.69 |
| | 16 | 68.49 | 5.78 | 8.11 | 0.82 |
| | 24 | 84.27 | 3.24 | 11.39 | 0.37 |

### Diameter-class structure

The population quantities of *Q. mongolica*, *Tilia mandshurica* and *Ulmsis Laciniata* linearly decreased with the increase in diameter class in sunny slope after 5-year closed treatment (Fig. 1). The *Q. mongolica* population was mainly made up of small diameter-class individuals. With the rising of diameter class, tree number of *Q. mongolica* population decreased greatly, however the population quantity of *T. mandshurica* and *U. Laciniata* didn't change obviously with the increase of diameter class (Fig. 1). The growing status of the trees with 5-year closed treatment was basically same as that with 16-year closed treatment. The percentage of seedlings in diameter-class 2 increased with the increase of canopy density. After 16-year closed treatment, when the diameter class was over 4, the population quantity of *Q. mongolica* population did not change obviously comparing to that in 5-year closed treatment. The result indicated that *Q. mongolica* played a dominant role after 16-year closed treement. In the sample plots, the growth of *Q. mongolica* population after 24-year closed treatment presented a stable status and its seedlings were in a large quantity. Similar to the 16-year closed treatment, population quantity of *Q. mongolica* was stable when diameter class was over 4. The population of *T. mandshurica* declined significantly and tended to disappear in large diameter class. The population of *U. laciniata* increased with the increase in diameter class, which indicated that this species might be shade-tolerant in relative shade environment.

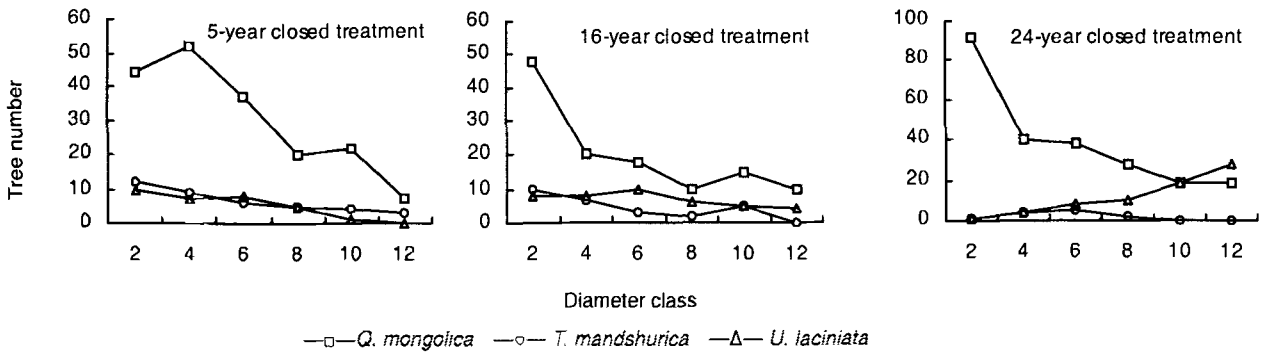


**Fig. 1 Diameter-class structure of main arbor populations with different closed time in sunny slope**

In the shade slope, the population quantities of *Q. mongolica*, *T. mandshurica* and *U. Laciniata* after 5-year closed treatment decreased linearly with the increase in diameter class. These populations were considered as progression population (Fig. 2). The diameter-class structure presented a similar trend in shade and sunny slopes. *Q. mongolica* population had relative large quantities of seedling. Compared to *Q. mongolica* population, the decreased popula-

tion quantities of *T. mandshurica* and *U. Laciniata* were less than that of *Q. mongolica*. There was almost no difference in quantity of *Q. mongolica* forest above diameter-class 4 between 16-year closed treatment and 24-year closed treatment and there was little variability in population quantity on all diameter classes. This revealed that *Q. mongolica* population had taken the dominant position. The *T. mandshurica* population had fallen into recession situation after 16-year closed treatment and still kept recession trend with decline of population quantity. The population quantity *U. Laciniata*, after 16-year closed treatment, distributed evenly in various diameter classes and the population structure was stable, but it fell into recession situation after 24 years.

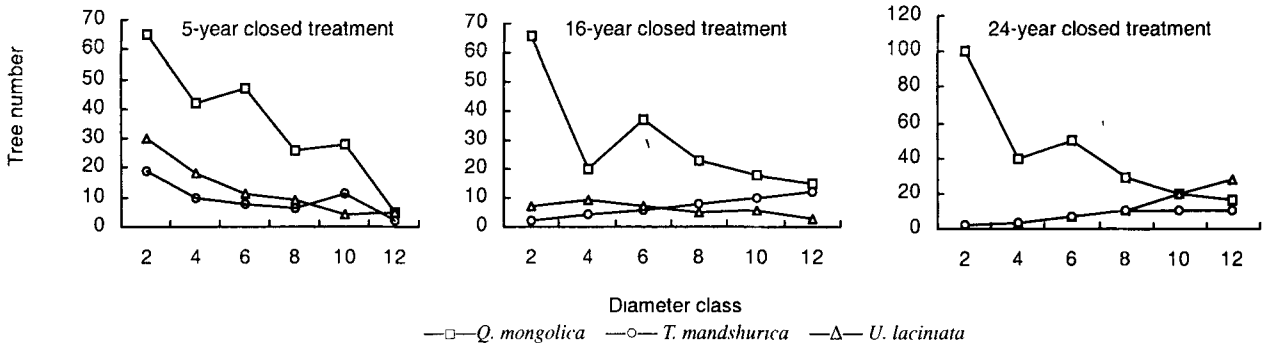


**Fig. 2 Diameter-class structure of main arbor population with different closed time in shade slope**

## Conclusions

*Q. mongolica* after different time of closed treatment invaded and became a dominant species step by step in Korean pine destroyed forest blank and was difficult to be replaced by other pioneer trees because it has characteristics of anti-drought, anti-cold and anti-barren (Zhou 1980; Wang 1986). With the increase of canopy density, the percentage of seedlings in diameter-class 2 became larger than before, which can ensure its predominated position in the secondary forest. Within the plots after 5-year closed treatment, quantities of various populations linearly decreased along with the increase of diameter class. Regarding the plots the larger canopy coverage resulted in recession both in *T. mandshurica* and *U. Laciniata* populations after 16-year closed treatment, which had turned into associated species of *Q. mongolica* forest. The various populations with diameter class above 4 were relatively stable. The results indicated that when diameter was over 7-9 cm (Class 4) the growth of the three populations became stable. However the *T. mandshurica* and *U. Laciniata* populations cannot adapt to the environment, whether in sunny or shade slopes, compared to *Q. mongolica* forest. After 24-year closed treatment *Q. mongolica* forest had the absolutely superiority.

The canopy coverage in sunny slope increased more quickly than that in shade slope. The seedling height of every species of trees, especially for the trees in the diameter-class 2 (0-3 cm), in shade slope was higher than that in sunny slope (Fig.1 and Fig.2). The trend of recession of *T. mandshurica* or *U. Laciniata* population in sunny slope was more obvious than that in shade slope.

From practical view, the closed treatment time in *Q. mongolica* forest should be shorter in sunny slope than in shade slope. With the prolonged time of closed treatment, the vegetation will recover and develop to pure *Q. mongolica* forest. Provided *T. mandshurica* and *U. Laciniata* populations were cultivated as target species, the closed treatment method should not be implemented and the *Q. mongolica* population should be controlled in the early phase of vegetation recovering.

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